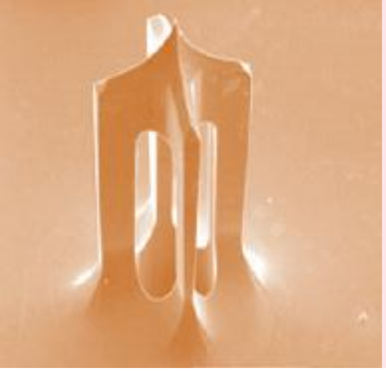
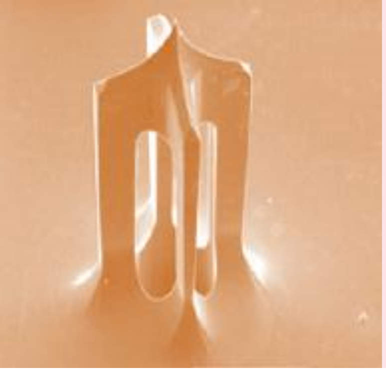


MEMS 103
Biomedical Applications of Microsystems

Presented by

Southwest Center for
Microsystems Education
-SCME-



SCME

Southwest Center for Microsystems Education

SCME is a National Science Foundation Advanced Technological Education (ATE) Program at the University of New Mexico.

We offer professional development and educational materials to excite and engage high school, community college and university students in the field of Microsystems (MEMS) technology.

Support for this work was provided by the National Science Foundation's Advanced Technological Education (ATE) Program through Grants #DUE 0992411.

Our Presenters

Barb Lopez

Research Engineer, University of New Mexico and Instructional Designer, SCME

Mary Jane (MJ) Willis

Instructional Designer, SCME and retired Chair for the Manufacturing Technology Program – Central New Mexico Community College

Objectives for Today

- Brief overview of what SCME can do for you
- Define bioMEMS
- Identify areas impacted by bioMEMS
- Discuss specific bioMEMS applications
- Explain how specific bioMEMS work

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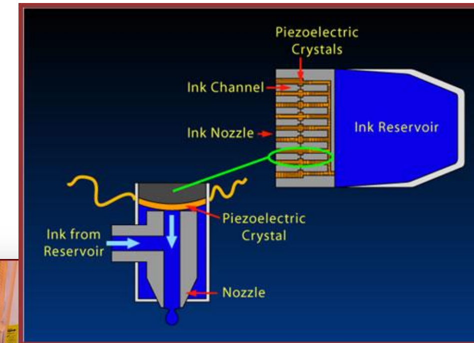
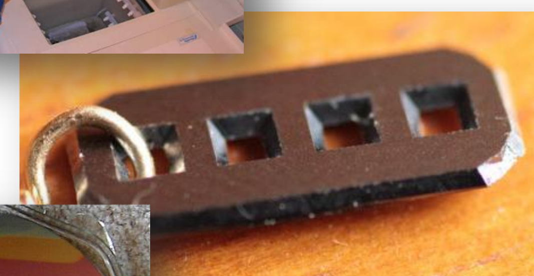
Educational Materials





To date SCME offers

- 150 Shareable Content Objects (SCOs)
  - Informational Units / lessons
  - Supporting activities
  - Supporting assessments
- 37 Learning Modules in the areas of
  - Safety
  - Microsystems Introduction
  - Microsystems Applications
  - Bio MEMS
  - Microsystems Fabrication
- 11 Instructional Kits
- All are available @ scme-nm.org

SCME
Southwest Center for Microsystems Education

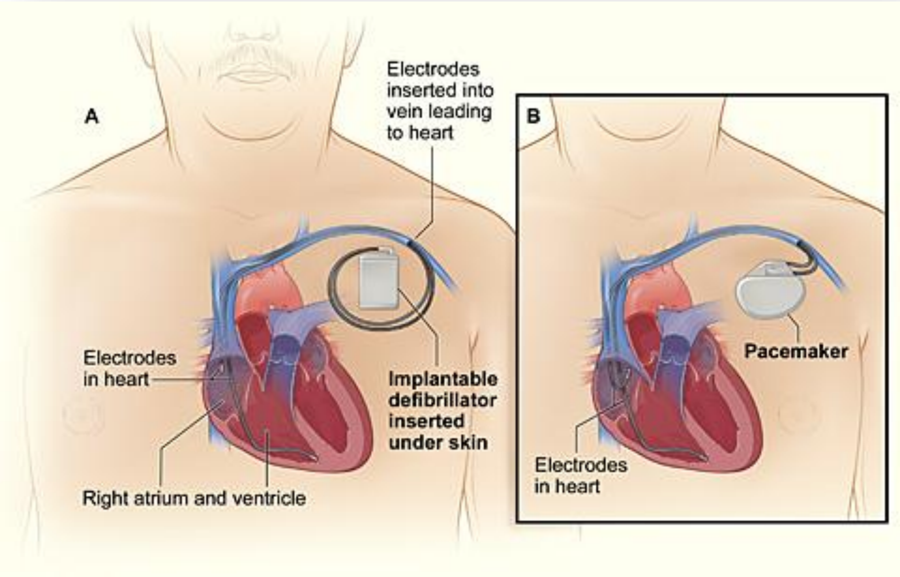
Professional Development

- 4 to 5-day workshops
- 2-day workshops
- 1-day workshop
- Conferences and conference workshops
- Create hubs at other colleges to teach our workshops
- Webinars

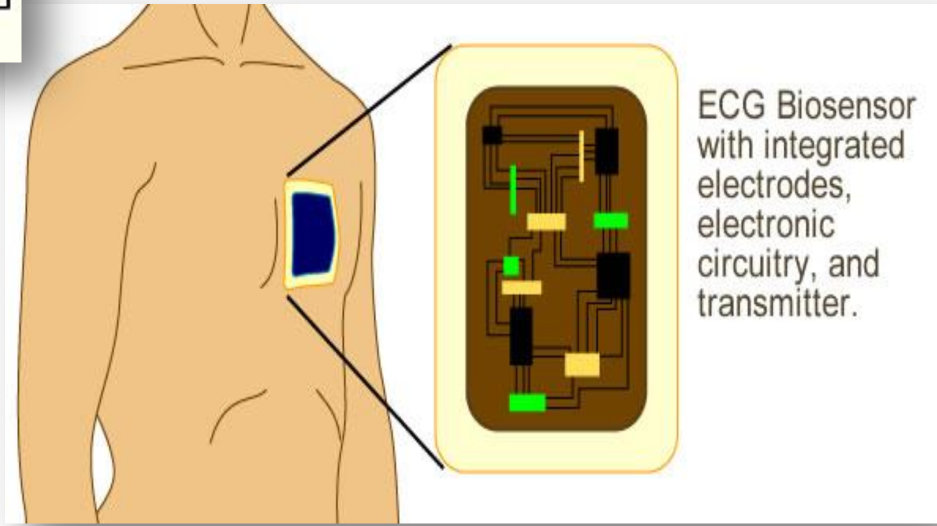
What are bioMEMS?

- MEMS that have biological and/or biomedical functions or applications.
- Any MEMS used in the medical field to perform functions such as
  - monitoring pressures, temperatures and movement,
  - transmit optical and electronic signals, and transport fluids or
  - actuate a micro-size component.
- MEMS used in the medical field that incorporate biological molecules as an integral part of the device.

MEMS as bioMEMS

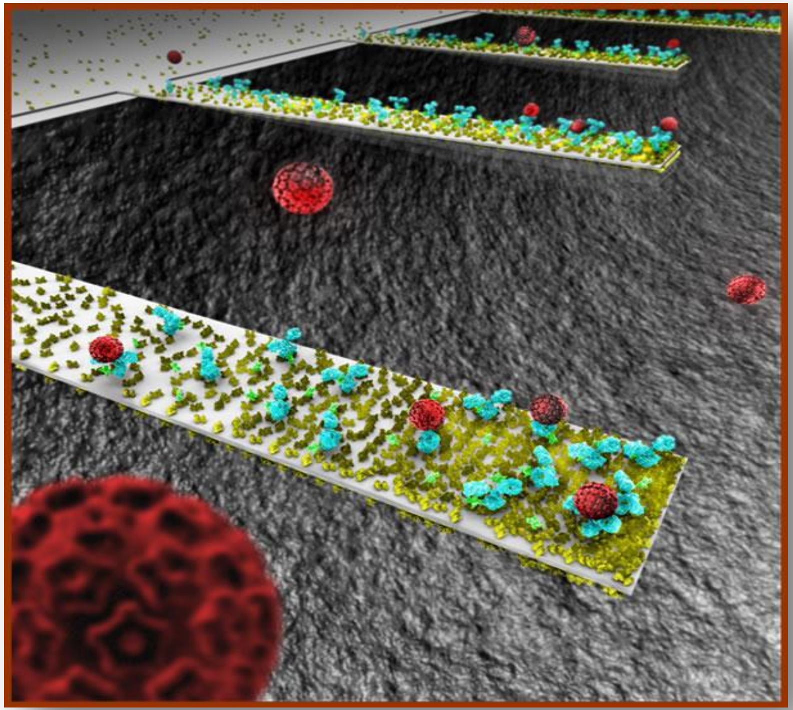


MEMS accelerometers found in pacemakers and defibrillators



MEMS electrodes and RF transmitters found in electrocardiogram (ECG) patch monitors

MEMS and Biomolecules

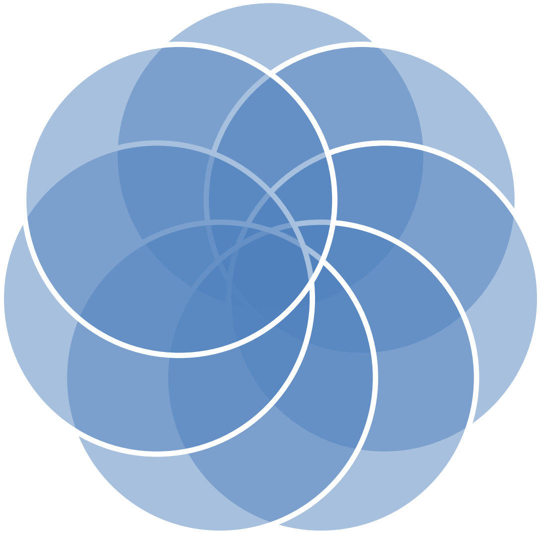


Micro and nano-sized cantilevers used to identify a virus (red sphere) in a sample. The captured biomolecules are specific antibodies (green particles) *[Image generated by and courtesy of Seyet, LLC].*

Lab-on-a-Chip (LOC)

[Printed with permission. From Blazej,R.G.,Kumaresan,P. and Mathies, R.A. PNAS 103,7240-7245 (2006)]

Areas Impacted



Clinical Laboratory

Poll - Areas Impacted

Let’s take a poll and see if you were listening.

Which of the following statements BEST describes bioMEMS?

A. Biomems are micro-size devices that use biomolecules to sense, detect, or actuate.

B. Biomems use conventional MEMS components such as accelerometers and pressure sensor to perform medical functions.

C. Biomems consists of any microsize device that is used in the medical field to perform a function such as sensing, signal conversion, or actuation, just to name a few.

Poll - Areas Impacted

Answer:

Which of the following statements BEST describes bioMEMS?

A. Biomems are micro-size devices that use biomolecules to sense, detect, or actuate.

B. Biomems use conventional MEMS components such as accelerometers and pressure sensor to perform medical functions.

C. Biomems consists of any microsize device that is used in the medical field to perform a function such as sensing, signal conversion, or actuation, just to name a few.

Standard Clinical Laboratory Tests

- Analyze body fluids, cells and other components like DNA and RNA
- Look for the presence of pathogenic entities such as bacteria, viruses and other microorganisms
- Analyze the chemical content of fluids
- Match blood for transfusions

BioMEMS in Clinical Labs

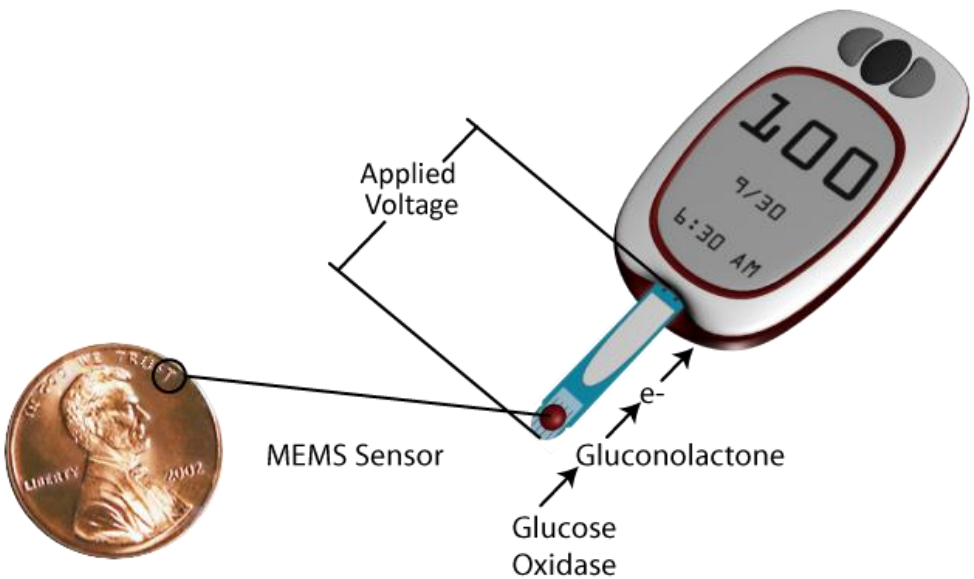
In clinical laboratories, the incorporation of MEMS technology has several advantages:

- Decreased costs as a result of miniaturization
- Smaller sample size
- Ability to do the tests at home or in the field (point of care testing)
- Ability to multiplex tests (test for several things in one sample)

Clinical Lab Tests at Home

The **Multiplo** is a testing device that simultaneously tests for the antibodies to human immunodeficiency virus (HIV) and hepatitis C virus (HCV).

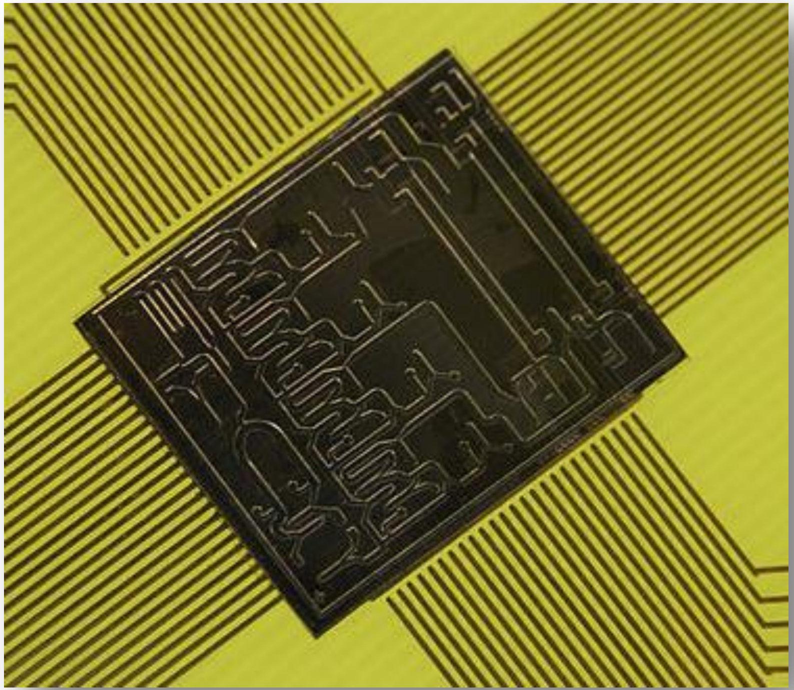
The Multiplo HIV/HCV Antibodies Test
(drawing does not represent actual device)



Blood Glucose Monitor
Works on the basis of a glucose oxidize reaction with blood plasma. The transducer at the end of the sensor stick is 1 mm long by 200 µm wide. Newer glucose sensor use even smaller transducers.

Lab-on-a-chip (LOC)

- The LOC is a class of devices that integrates one or more clinical tests on a micro-sized device.
- One application is a device that performs a blood analysis using a minute sample of blood, about as much as a mosquito bite. Depending on the device, the blood can be analyzed for various blood counts (e.g. WBC, RBC, platelets), immune deficiencies, or infections.



This LOC uses microfluidics to analyze a liquid sample.

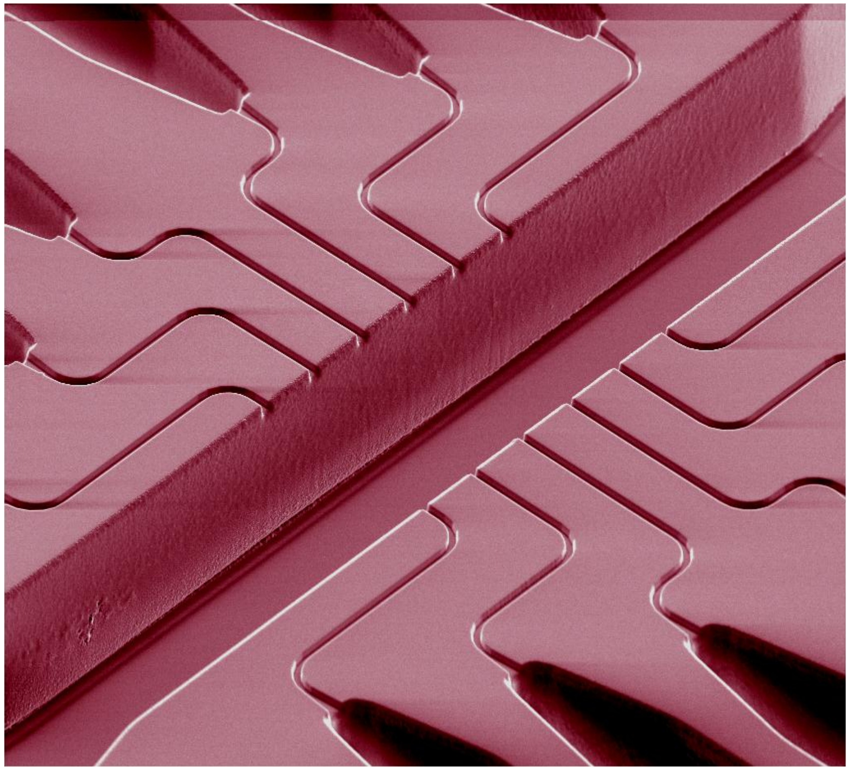
[Image courtesy of Maggie Bartlett, NHGRI – Public Domain]

The Lab-on-a-chip (LOC) Concept

The basic concept of LOC fabrication is to

- create several microchannels for a liquid sample to flow into, as well as
- several microchambers with
- functionalized surfaces.

When the sample is applied to the input chamber, various analytes within the sample are captured by specific probes within the chambers.



A fabricated microfluidic surface showing microchannels and chambers..

[Image courtesy of BioPOETS, UC-Berkeley]

Lab-on-a-chip (LOC)

- This LOC is a mini-lab tested successfully on board the International Space station (ISS).
- This LOC detects the presence of bacteria or fungi on the surfaces of a spacecraft far more rapidly than standard methods of culturing which can take days for a final analysis.
- This LOC identified dirty samples in 2 minutes!

This LOC liquid samples to identify .

[Image courtesy of NASA]

Lab-on-a-chip (LOC)

The Possibilities

- environmental monitoring
- cell sorting
- protein separation
- detection of biological weapons
- blood analysis
- drug screening systems
- drug development
- portable DNA analysis

Diagnostic MEMS

Wouldn't it be nice to have a medical device that could identify clues within our bodies to tell us what our ailments might be?

If you have ever watched Star Trek, you can imagine what such a device would be like – a handheld optical or x-ray scanner used externally to “see” what is happening inside. The possibility of such a device is becoming closer to reality.

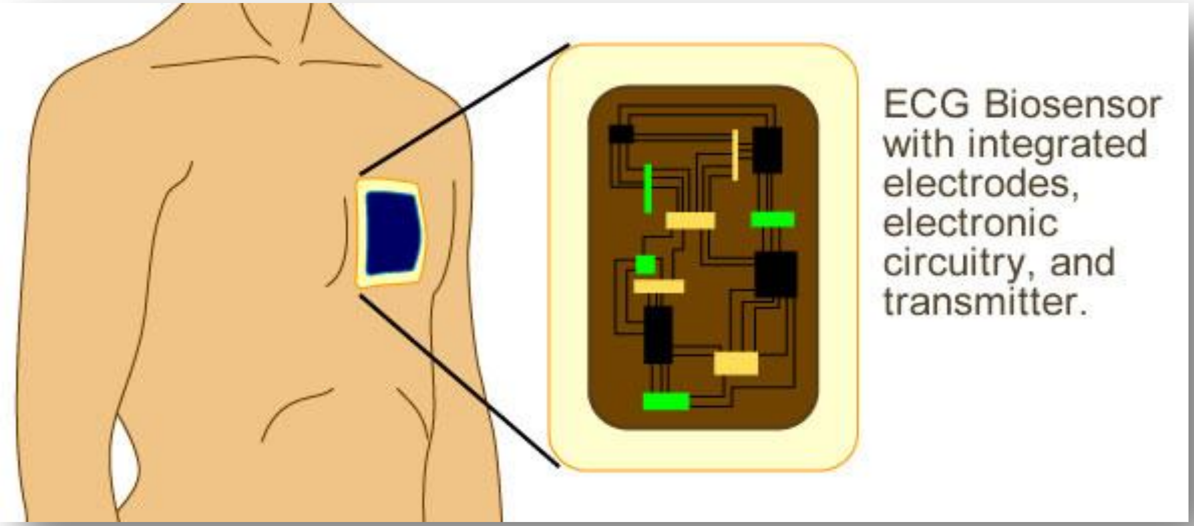
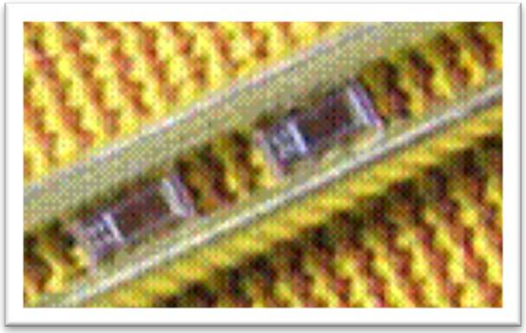


Illustration of a MEMS electrocardiogram (ECG) patch monitor. Such a device is being developed by Belgium's IMEC for monitoring a patient's arrhythmias all day and night. Patients that are high risk for cardiac events can wear this devices 24/7.

Diagnostic MEMS

BioMEMS Diagnostic devices can be

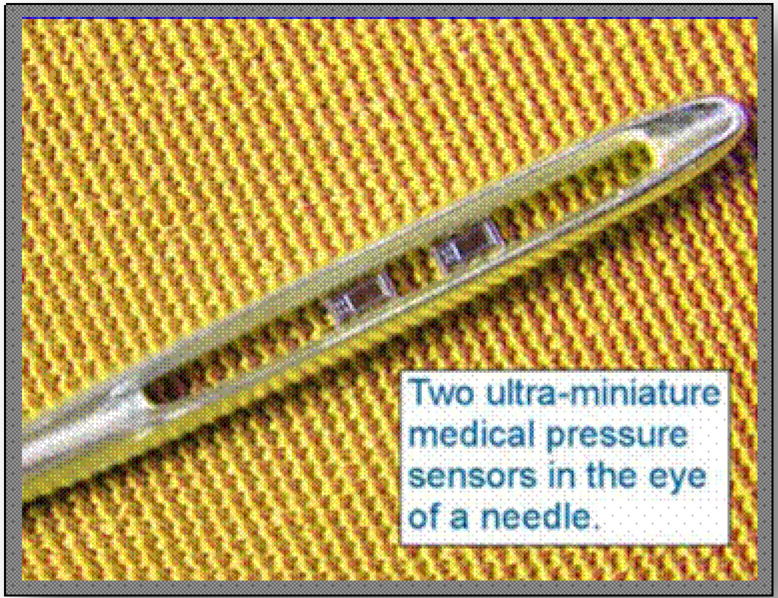
- cost effective,
- easier to administer, and can be
- used for in vivo (internal) or in vitro (external) monitoring.



Integrated Sensing Systems Sensors
[Image courtesy of ISSYS]

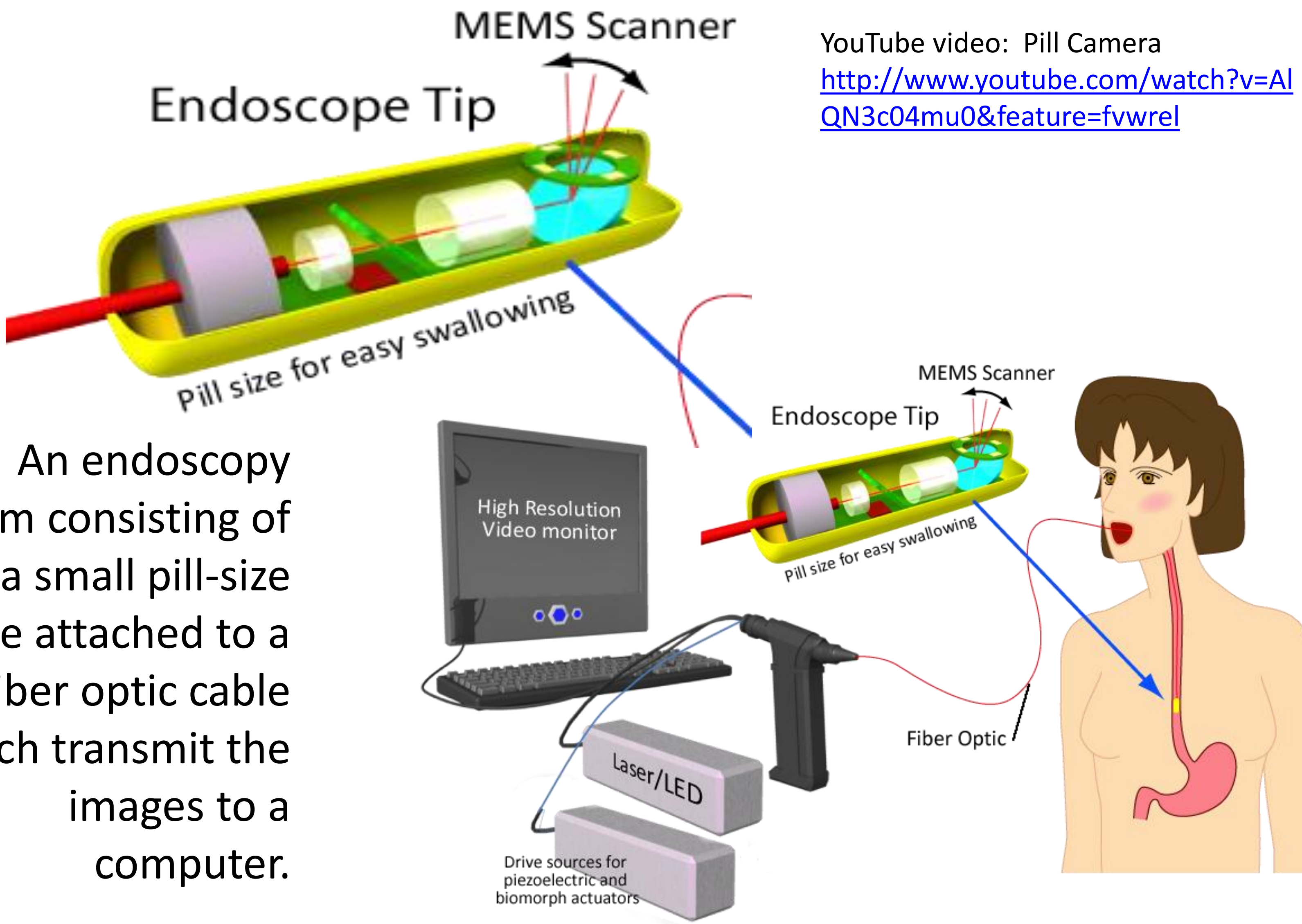
These implantable pressure sensors (right) are wireless, self powered, and small enough for two of them to fit inside the eye of a needle.

Animal studies have shown that these sensors can measure cardiac output and intracranial pressure.



Medical Imaging Diagnostics

YouTube video: Pill Camera
http://www.youtube.com/watch?v=AlQN3c04mu0&feature=fvwrel

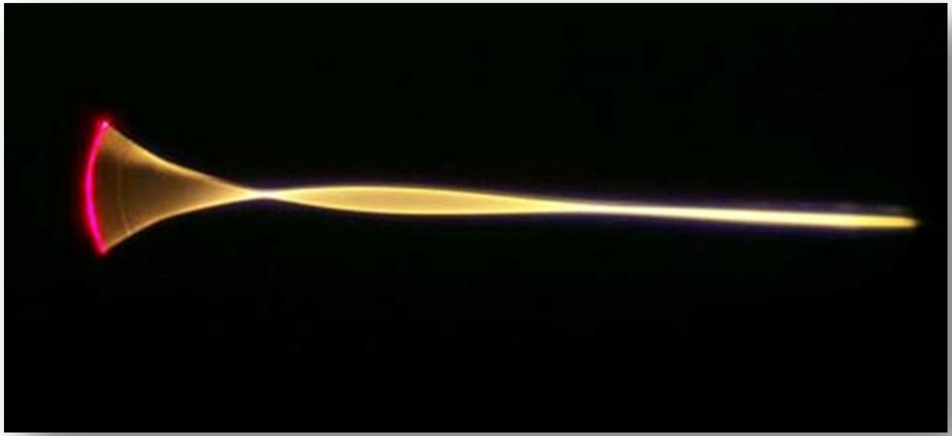


An endoscopy system consisting of a small pill-size device attached to a fiber optic cable which transmit the images to a computer.

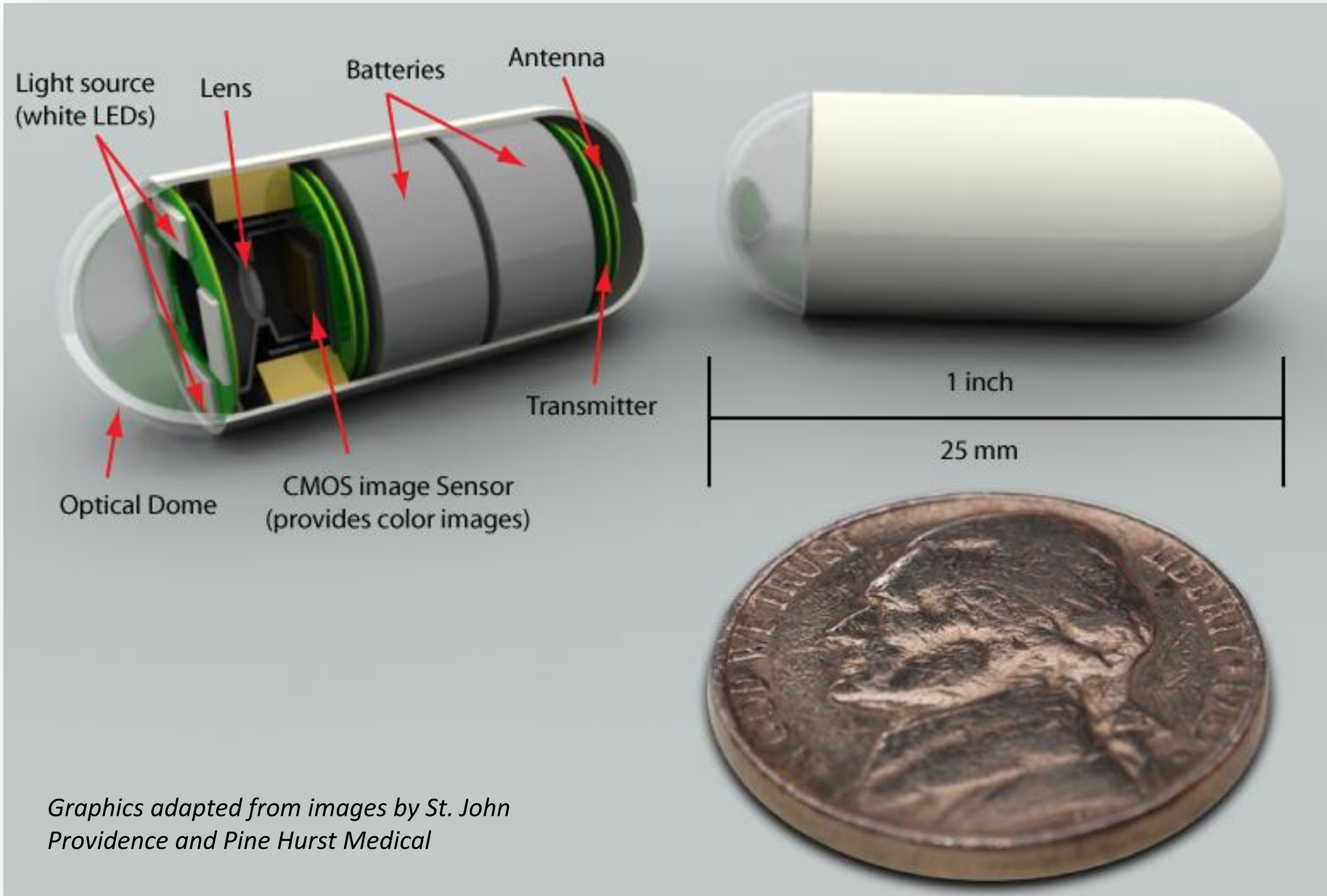
Micro-Optical Scanner

The micro-optical scanner is an optical fiber and a micro- device placed inside the 1 mm diameter tip of a flexible endoscope. The fiber scanner is driven in one dimension with a piezoelectric actuator, producing a line scan. By knowing and controlling the fiber position and acquiring backscattered intensity with a photodetector, an image is acquired.

Microscope image of the Micro-optical fiber scanner. The diameter of the fiber tip, where red laser light is exiting, is approx. 10 microns.
[Image Courtesy of Eric Seibel and Mark Fauver]

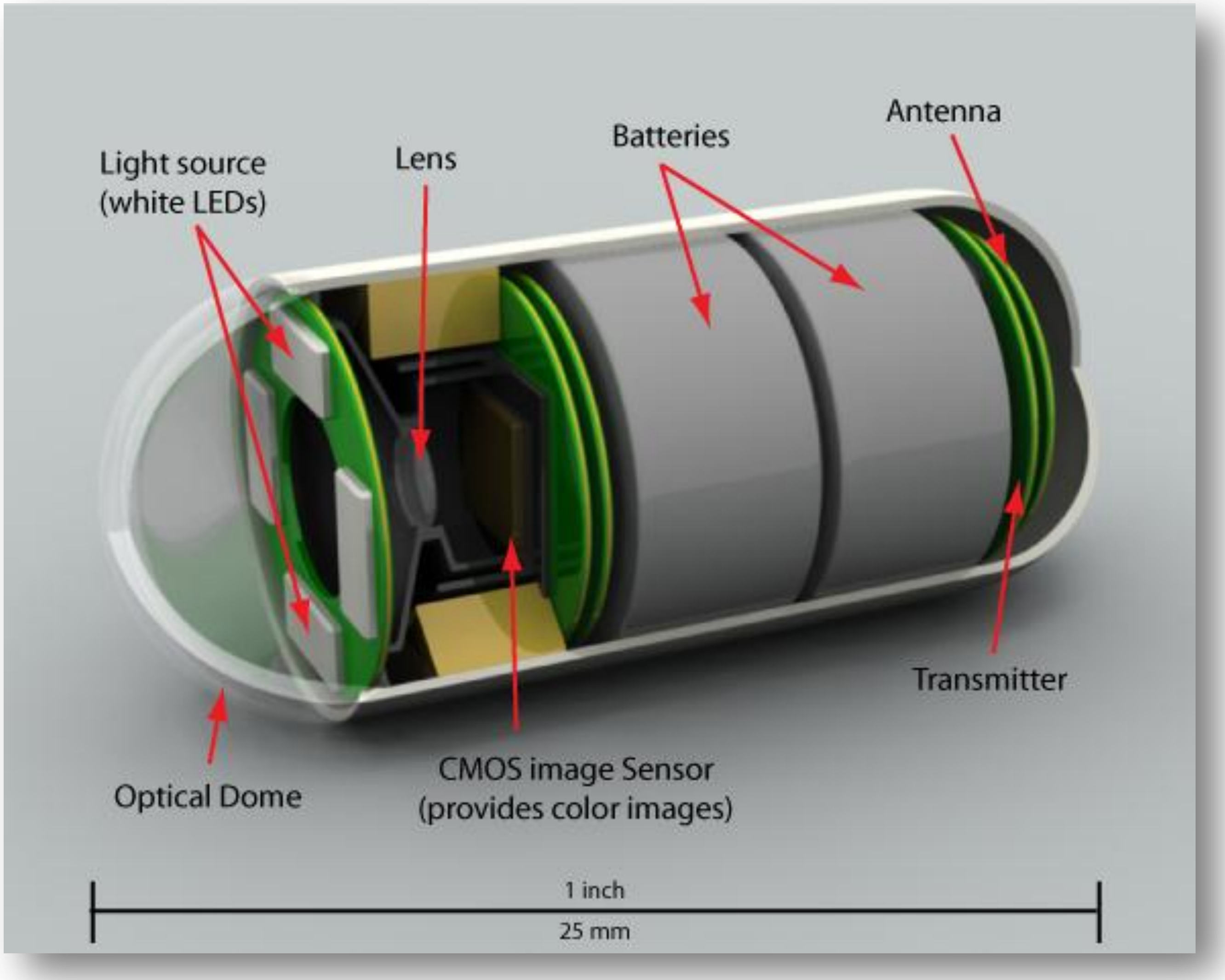


Capsule Endoscopy



Graphics adapted from images by St. John Providence and Pine Hurst Medical

Capsule Endoscopy



Patient Examinations and Monitoring

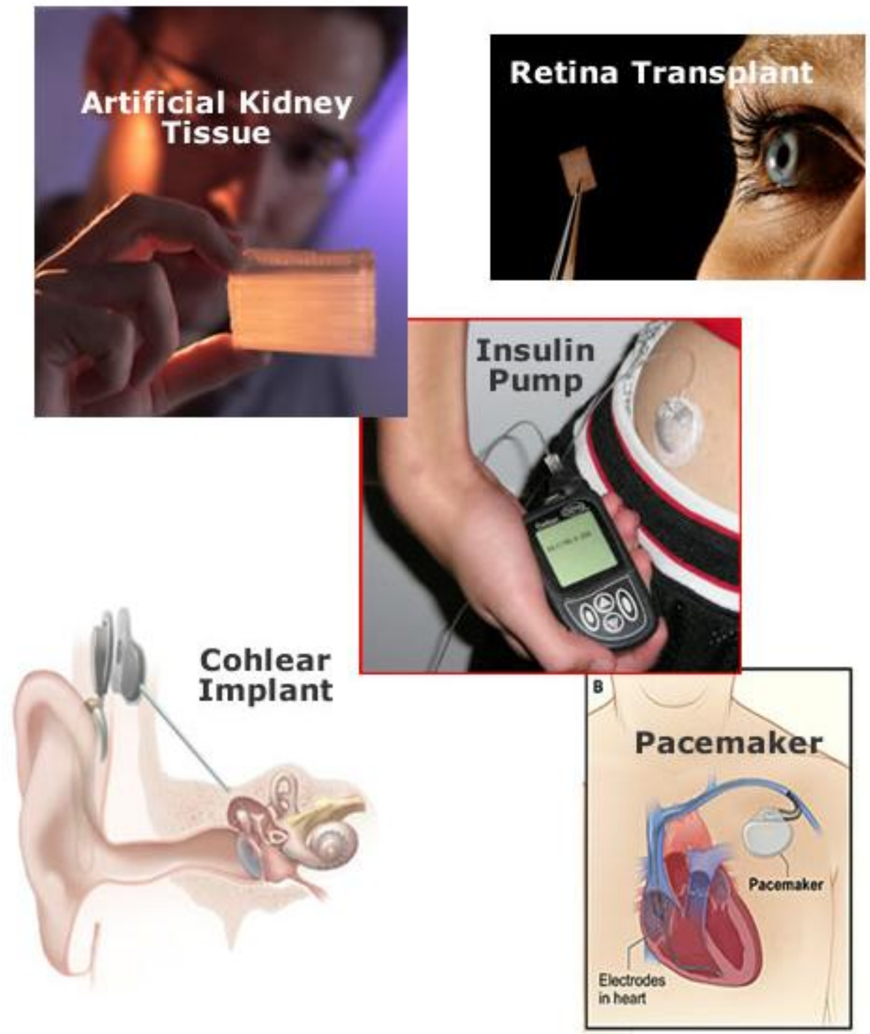
BioMEMS have been developed and proven to be effective for the following sensing and/or measurement applications:

- Measuring pressure in
  - arteries
  - spinal fluid
  - brain cavity
- Body temperature
- Force generated by muscles
- Skin tension
- Biomarkers
- Glucose
- Gases (i.e. oxygen and carbon dioxide)

Therapeutics

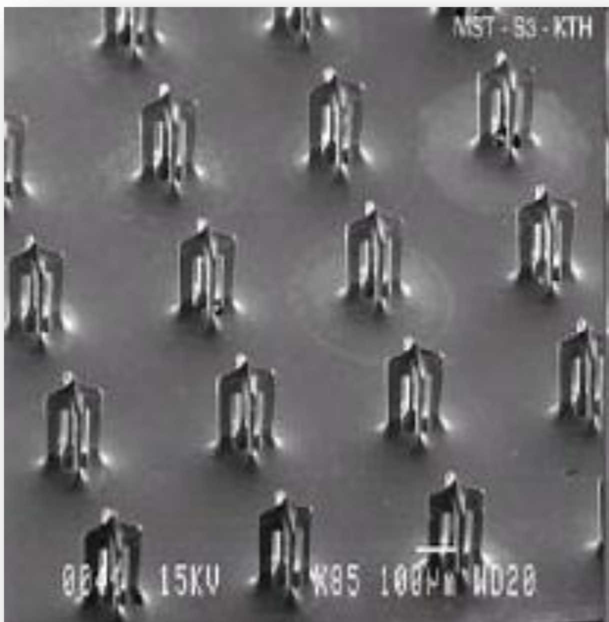
Therapeutic MEMS manage disease using 3 methods:

- In vitro (external) devices gather and process information.
- In vivo (internal) devices detect changes in a disease.
- Combination systems detect, monitor and manage disease.



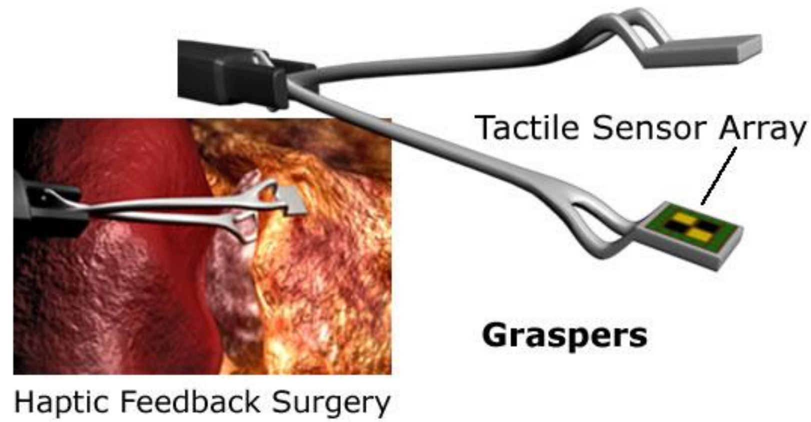
Therapeutics

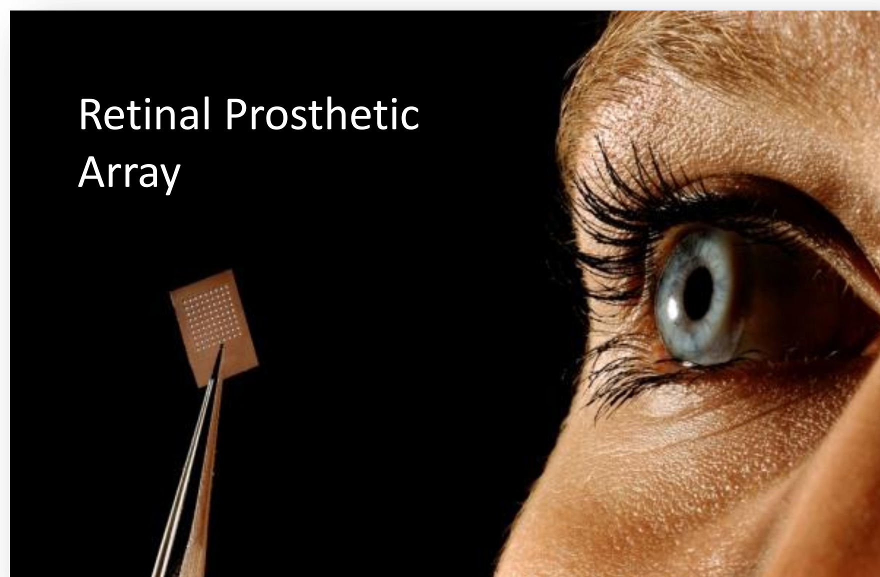
- Drug Delivery Systems
- Devices for invasive surgeries
- Artificial prosthesis



Microneedles

[Images courtesy of Debiotech SA/Switzerland]

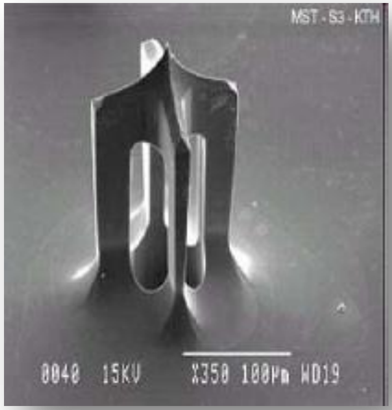




MEMS Based Drug Delivery Systems

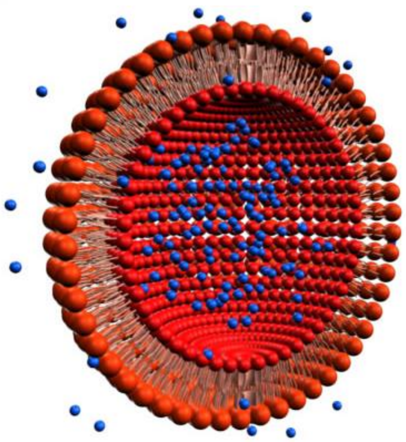
MEMS-based drug delivery:

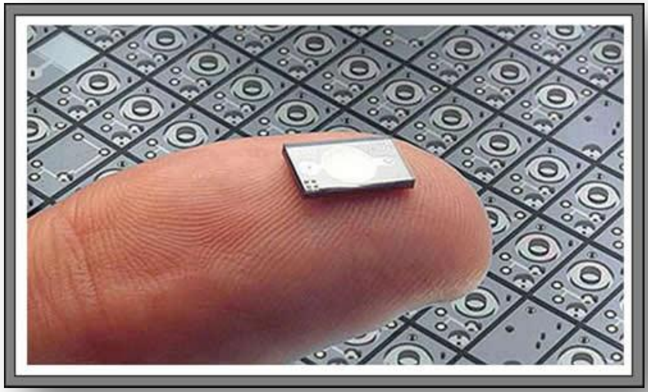
- Regulation of drug doses to be adapted based on physical activity, food ingestion, circadian rhythms
- Lower risk of infections
- Better uniformity and better localization



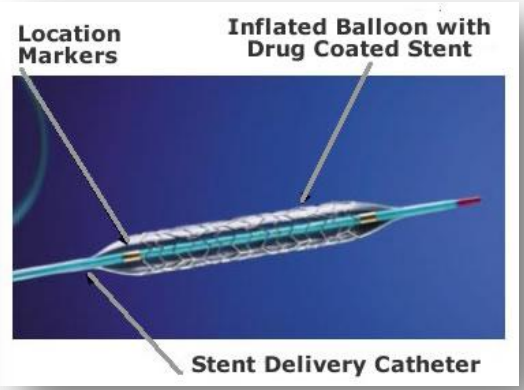
Microneedles
[Images courtesy of Debiotech SA/Switzerland]

Liposome





Micropump
[Image courtesy of Debiotech SA/Switzerland]



Nanopore Coated Stent
[Images courtesy of FDA]

Micro-Needles

- Low permeability
- Short enough to not reach nerves
- Combined with microfluidic sensors to administer a preset dose as needed

Microneedle Arrays

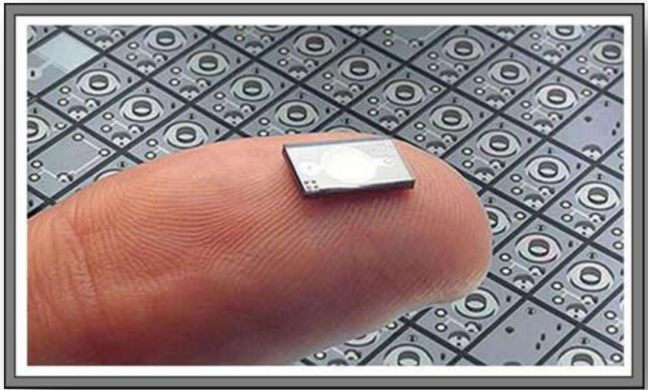
NanoJet

Images courtesy of Debiotech SA/Switzerland

Drug Delivery – Insulin Delivery

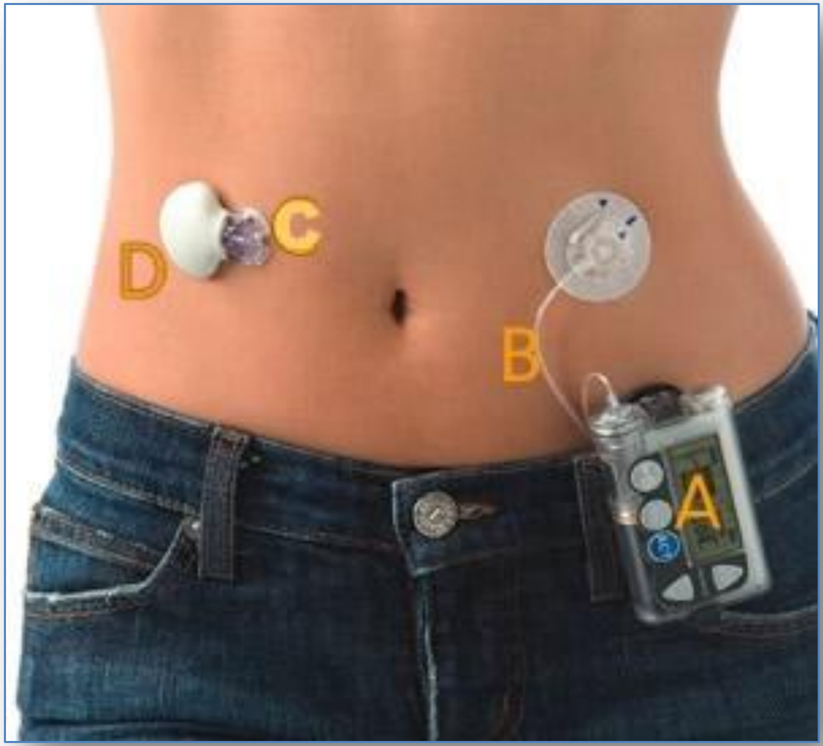
Insulin pump, with MiniLinkTM transmitter and infusion set

- External pump & computer
- Soft cannula that delivers insulin
- Interstitial glucose sensor
- Wireless radio device that communicates with the computer



Micropump for insulin delivery

Image courtesey of Debiotech SA/Switzerland

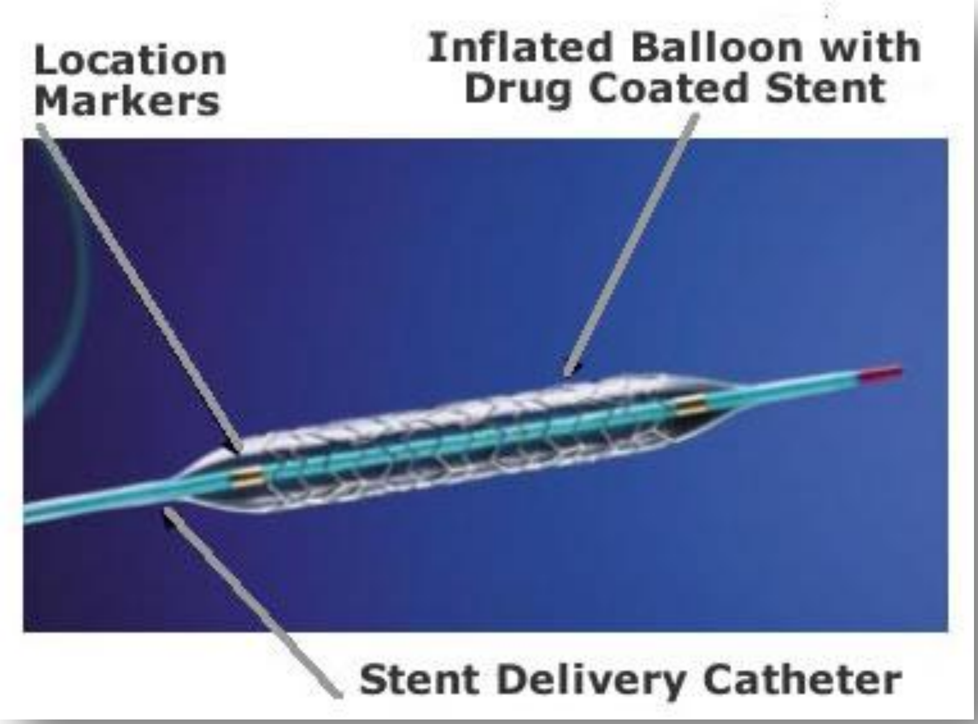


MiniMed Paradigm[R] 522 insulin pump, with MiniLinkTM] transmitter and infusion set.

[Printed with permission from Medtronic Diabetes]

Drug Delivery – Nanopore Coated Stents

- Used inside previously blocked arteries
- Stent coating is a medication slowly released to decrease restenosis
- Restenosis increases possibility of re-blockage.

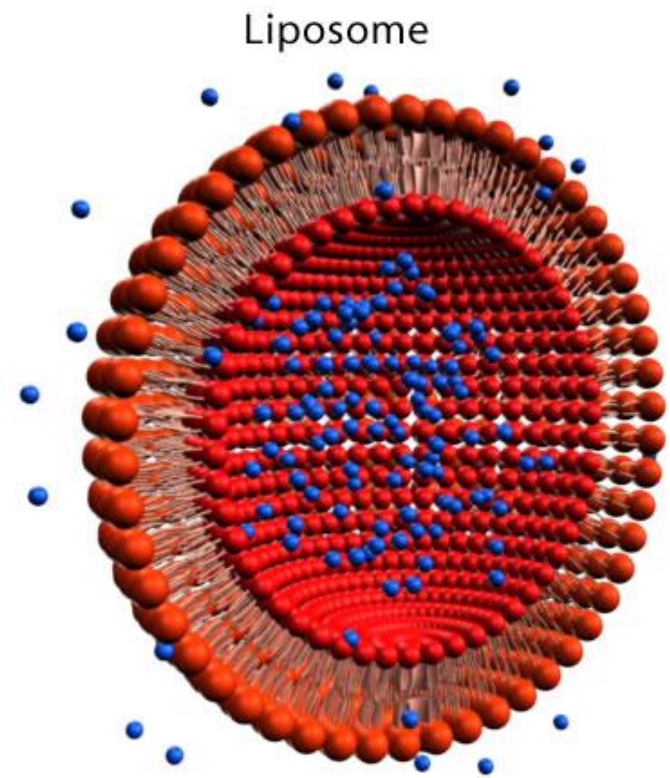


Drug-eluting Coronary Stent System

[Image source: FDA]

Drug Delivery – Liposome Vesicle

- Nano-sized cavity formed with cell membrane
- Filled with a drug (blue)
- Several can be injected into the bloodstream and guided to the target tissue
- The drug destroys or neutralizes the diseased tissue



Liposome vesicle filled with drugs (blue)

Artificial Retinal Prosthesis

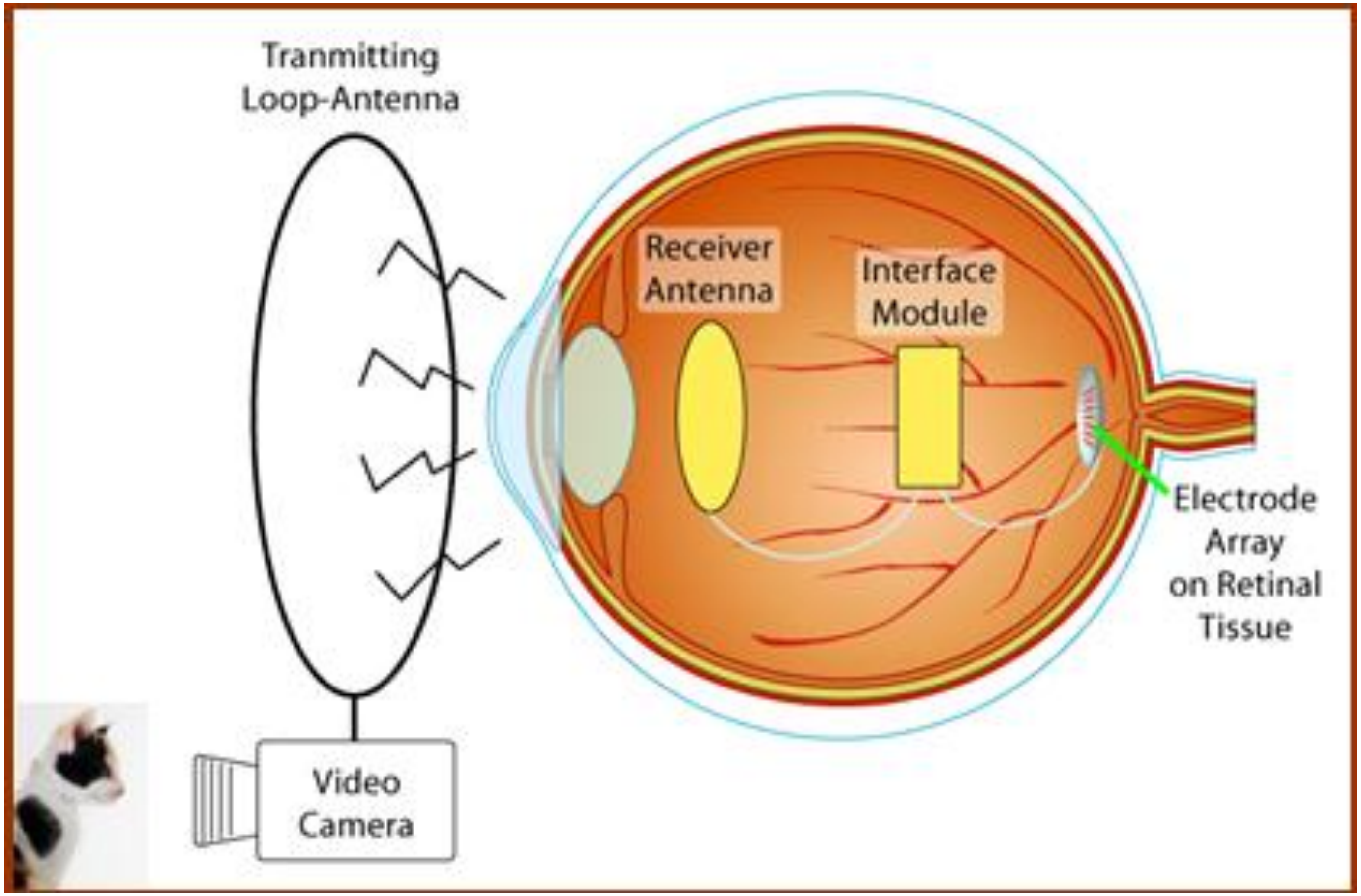
Argus™ Retinal Stimulation System

An artificial retina implanted onto the retina of a human eye

Prototype of a Retina Implant

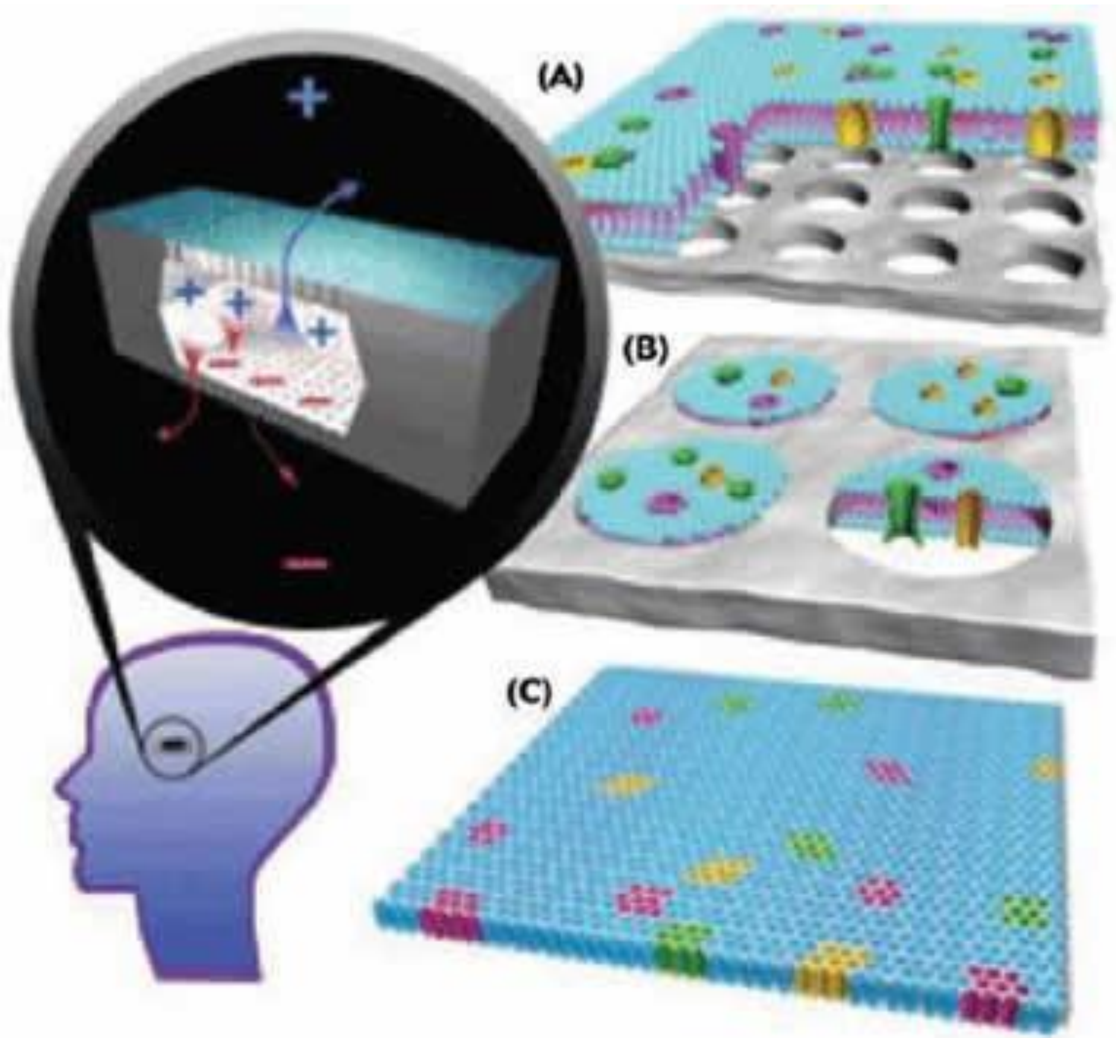
[Photo by Randy Montoya. Courtesy of Sandia National Laboratories]

MEMS Artificial Retina



- Bypasses destroyed photoreceptor cells
- Transmits signals directly to optic nerve.
- An electrode studded array

Powering the Artificial Retina



Battery Pack for Artificial Retina system
[Courtesy of Sandia National Laboratories]

What does the Patient See?

(Images generated by the Artificial Retinal Implant Vision Simulator devised and developed by Wolfgang Fink at the Visual and Autonomous Exploration Systems Research Laboratory, California Institute of Technology.)

This is what a patient with a retinal prosthetic should see.

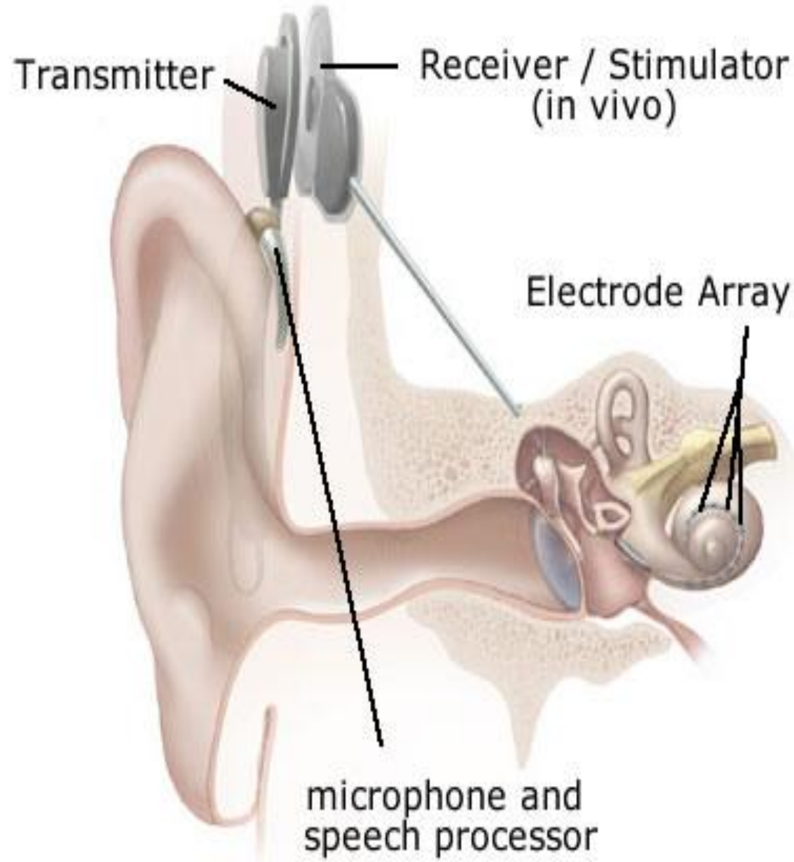
Increasing the number of electrodes in the retina array results in more visual perceptions and higher resolution vision.

Images produced by the artificial retina prosthesis

[Images generated by the Artificial Retinal Implant Vision Simulator]

Cochlear Implants

- Contains a microphone, a speech processor, a transmitter and receiver/stimulator, and an electrode array
- The implant gives a deaf person a useful representation of his environment.
- Cochlear Implants are a type of "neuroprosthetic"



[Modified from image courtesy of National Institute of Health]

Neuroprosthetics

Neuroprosthetics are electrical and mechanical devices that connect to the nervous systems to replace or supplement functions lost due to injury or illness.

http://www.youtube.com/watch?v=NypA012A4zE

Poll – Therapeutics

Let's take a poll

Which of the following devices are considered neurosprothetics?

A. Cochlear and retinal implants
B. Capsule and fiber optic endoscopy
C. Microneedles and LOCs
D. All of the above are considered neuroprosthetics.

Poll – Therapeutics

Answer:

Which of the following devices are considered neurosprothetics?

A. **Cochlear and retinal implants**

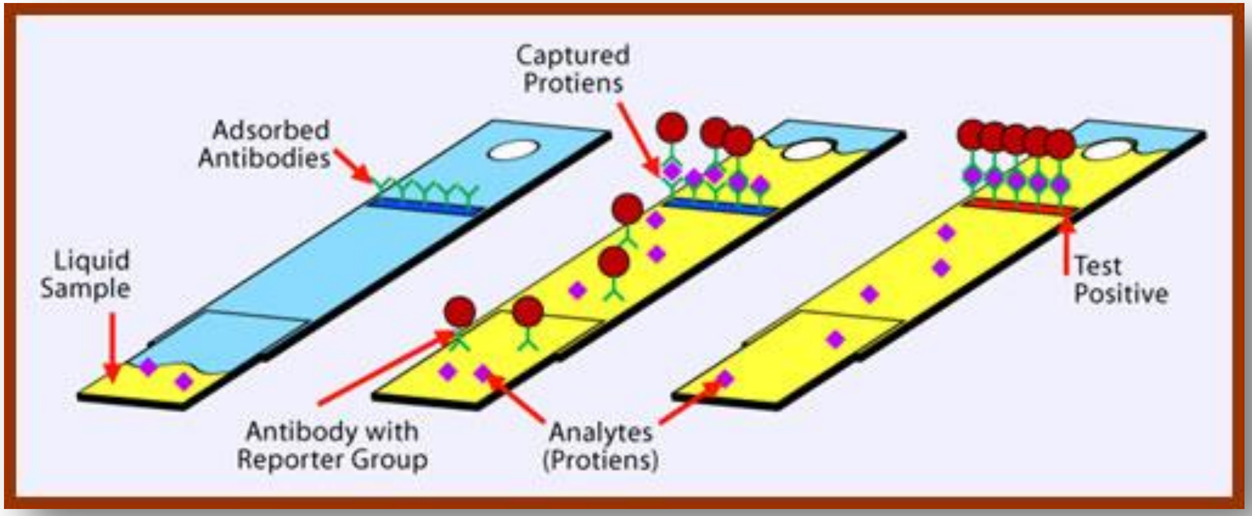
B. Capsule and fiber optic endoscopy

C. Microneedles and LOCs

D. All of the above are considered neuroprosthetics.

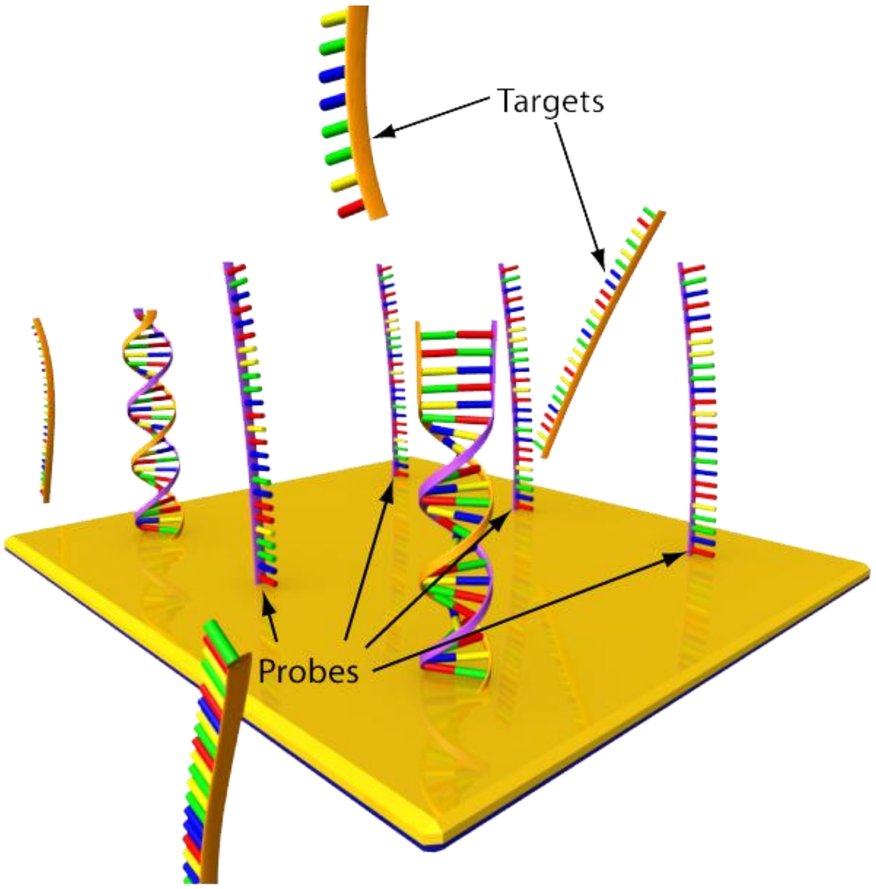
Biomarkers for Diagnostics

- Pathogenic agents such as bacteria and viruses cause disease or illness to the host.
- Certain medical conditions produce specific antibodies or proteins (e.g., pregnancy produces a protein that can be detected in the urine).



Biomarkers for Diagnostics

- Cancer, infections and injuries can create physical changes in cells or tissues that can be seen and measured as well as antibodies to fight the infections.
- People can have specific genes that indicate a level of risk for developing a certain disease.



DNA Microarray used to identify specific genes or one's gene expression profile

Biomarkers and BioMEMS

Why do we need to identify biomarkers?

In order to diagnose particular diseases or conditions by identifying specific biological markers (e.g., antibodies, proteins, genes).

Scientists are still in the process of deciphering the biomarker landscape associated with specific disease states; however, as biomarkers are identified, bioMEMS diagnostic devices that isolate these biomarkers are being developed.

BioLOC's CD-Enzyme Linked Immunosorbent Assay - ELISA
(ELISATM – Printed with permission from BioLOC)

Micro-total-analysis systems (μTAS)

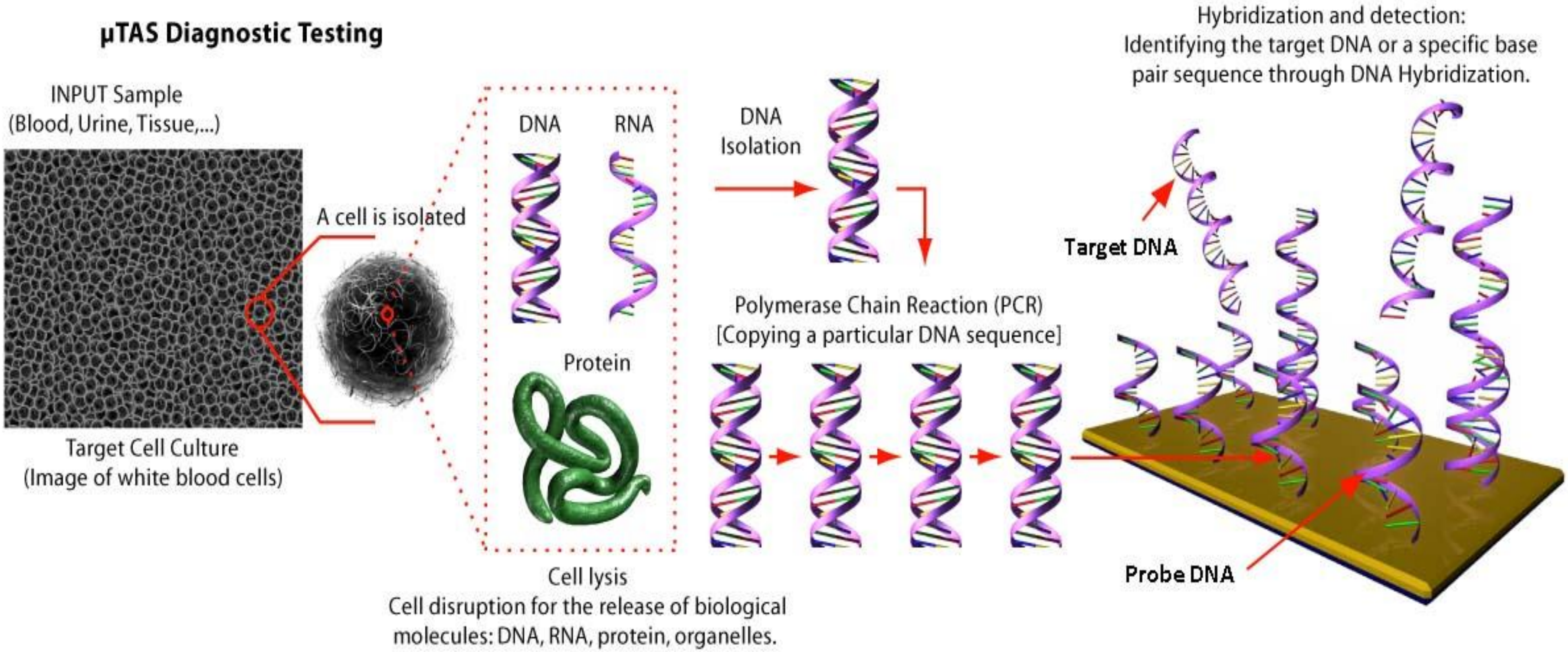
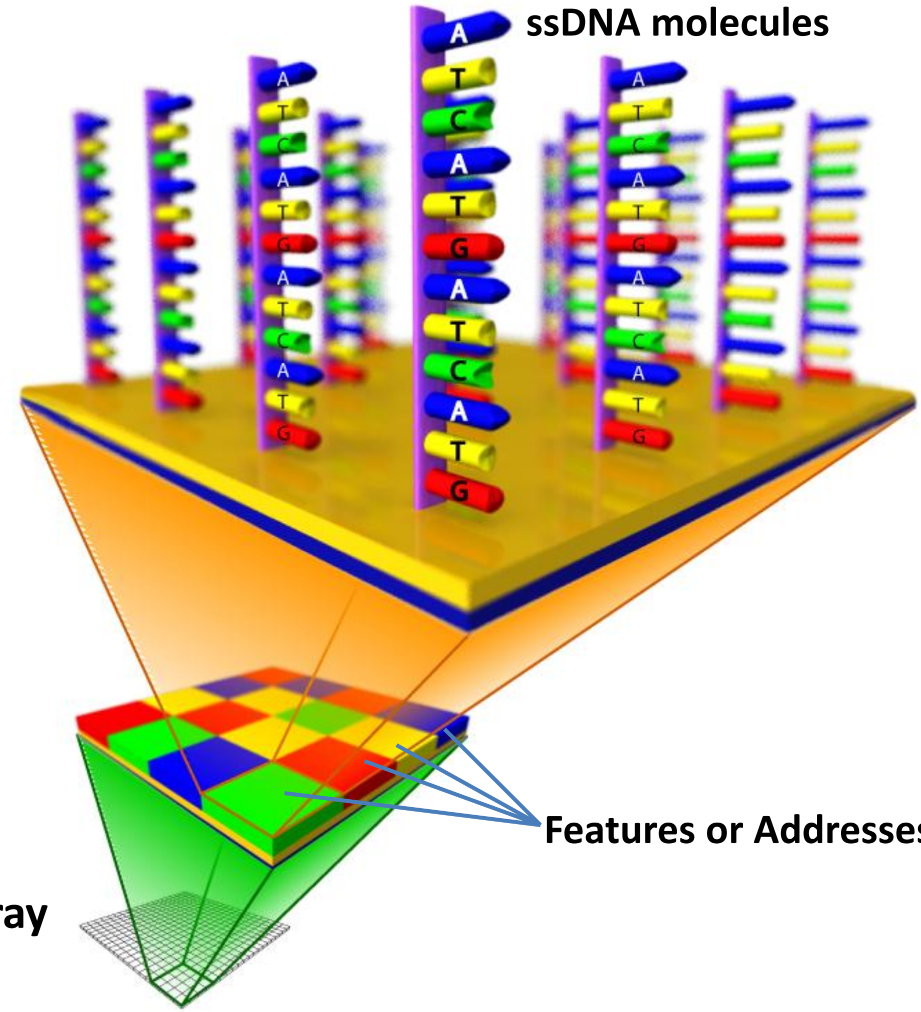


Image adapted from drawing created by Lennea Fletcher, Austin Community College

To learn more about μTAS, download the Diagnostic BioMEMS Overview Learning Module from scme-nm.org

DNA Microarray

- The substrate is divided into thousands of addresses or features.
- Each address has a different DNA sequence and hundreds of single-stranded DNA (ssDNAs) with that sequence.
- During a test, each address will combine with complementary DNA if available in the sample. The result is a double-stranded DNA (dsDNA) hybrid.



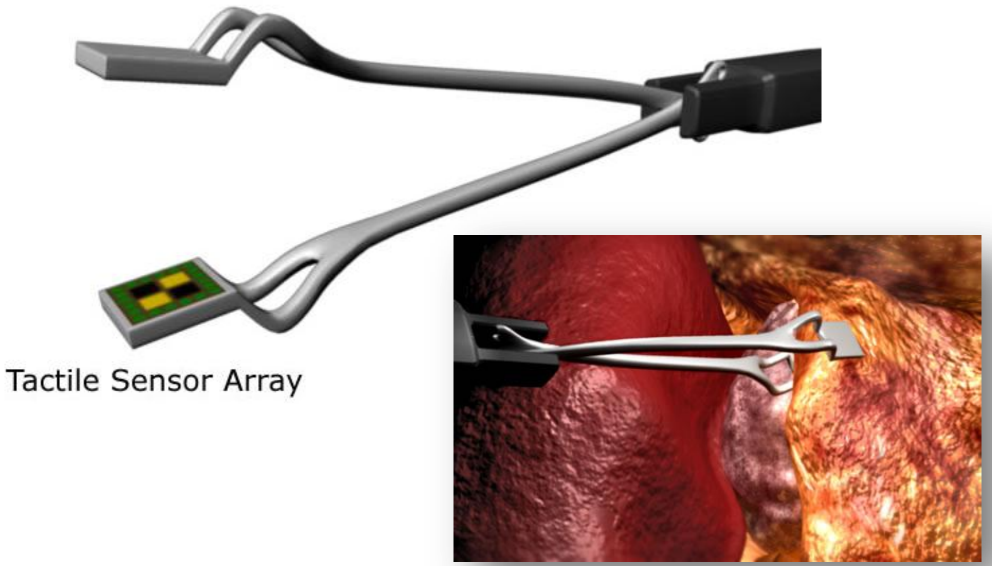
DNA Microarray

- Identify the presence of specific genes in a sample
- Map the gene expression (activity of genes) in a specific sample
- Identify the effect of drugs and drug dosage or environmental effects on one's genes

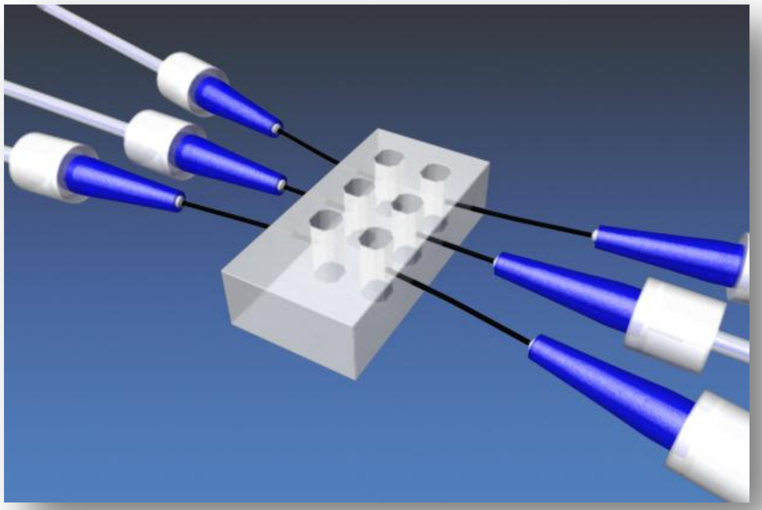
DNA microarrays do not diagnose.

To learn more about the DNA microarray, its applications, fabrication, and interpretation, please download the DNA Microarray Learning Module from our website. We also have a supporting kit called the GeneChip Model Kit that simulates the fabrication and interpretation processes.

Minimal Invasive Surgery (MIS)



Haptic Feedback Graspers with tactile sensor array



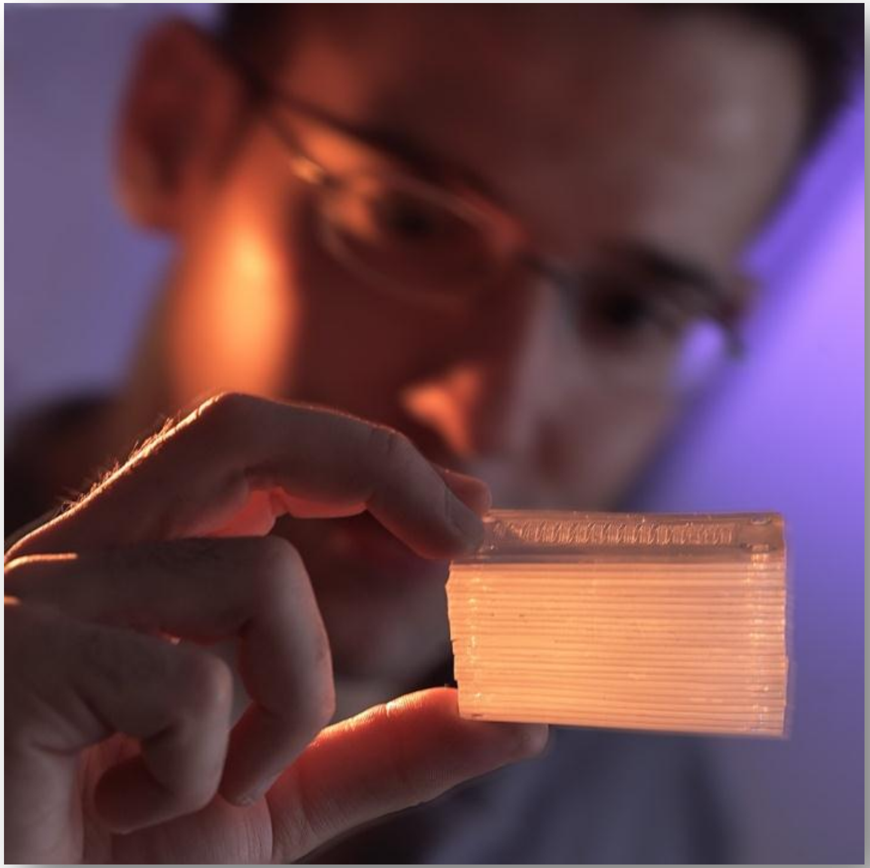
Pneumatic Balloon Actuator Array Prototype (Printed with permission of UCLA)

- Most MIS robots do not have a sense of touch (haptic feedback)
- Surgeons must rely on visual clues
- MEMS devices provide haptic feedback

Tissue Engineering

The Center for Integration of Medicine and Innovative Technology

- Developing a kidney dialysis unit to be worn around waist
- Building complex organs: kidneys, livers, replacement tissue
- MEMS enables replication of internal network of capillaries and vessels
- These tissues also allow for advanced tissue repair

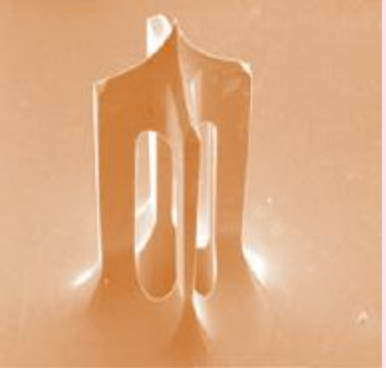


Artificial Kidney
[The Charles Stark Draper Laboratory, Inc.

SCME BioMEMS Learning Modules

This presentation was a brief overview of SCME's BioMEMS Learning Modules. Each of the following modules can be downloaded from scme-nm.org.

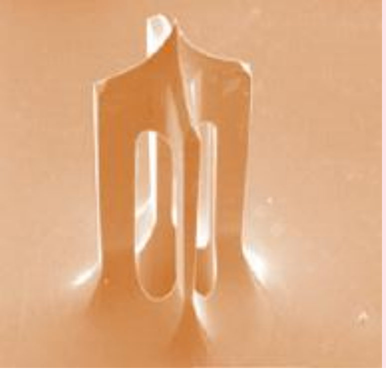
- BioMEMS Overview
- BioMEMS Applications Overview
- Biological Concepts (DNA, DNA to Protein, Cells, Biomolecules in BioMEMS)
- Diagnostic bioMEMS
- Therapeutic bioMEMS
- Clinical Laboratory Techniques
- DNA Microarray (supporting GeneChip Model Kit)
- Regulation of bioMEMS
- MEMS for Environmental and Bioterrorism Applications



Thank You For Joining Us

Barb Lopez
botero@unm.edu

Mary Jane (MJ) Willis
mjwillis@comcast.net



How Can We Serve You Better?

Southwest Center for Microsystems Education

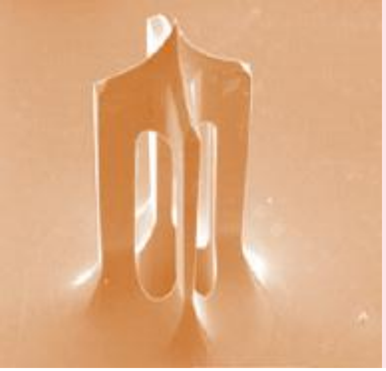
Please take 1 minute to provide your feedback and suggestions

https://www.zoomerang.com/Survey/WEB22DFNGEYR4W

Webinar Resources

To access this webinar recording, slides, and handout, please visit

www.scme-nm.org



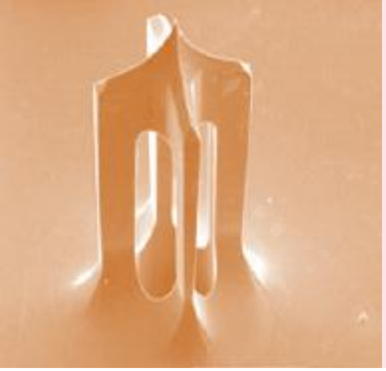
SCME Upcoming Webinars

Friday, March 2, 2012 — MEMS 201: Topics on Microsystems Materials – Crystal Structures

Thursday, April 12, 2012 — MEMS 202: Standard Micromachining Techniques

Thursday, May 3, 2012 — MEMS 203: Making a MicroPressure Sensor

All Webinars @ 1 PM ET



It was Fun!

Thank you for attending this SCME Webinar

MEMS 103
Biomedical Applications of Microsystems